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TECHNICAL NOTE

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FOURIER SERIES OPERATING PACKAGE

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SUMMARY

This report presents a computer program for multiplying, adding, differentiating, integrating, "barring" and scalarly multiplying "literal" Fourier series as such, and for extracting the coefficients of specified terms.

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INTRODUCTION

The Hansen Satellite Theory as modified by Musen[1] involves various manipulations of "literal" Fourier series, as such, before final numerical evaluation. To program this formulation it is necessary to represent cosines, sines, and constants in a special manner and thus manipulate the various Fourier series.

SPECIAL REPRESENTATION OF A SINE, COSINE, OR CONSTANT

It was decided to represent any term, including the constant term, of the Fourier series we are concerned with by two consecutive eight-place floating-point words. The terms of this series have the general form

$$A_n \cos (iF + jE + kW + lU)$$

or

$$A_n \sin (iF + jE + kW + lU)$$

and the values of F, E, W, and U are not used until final numerical evaluation. The first eight-place floating-point word represents the coefficient A_n in an entirely standard manner. The second eight-place floating-point word represents the sine or cosine term of up to four arguments in an *artificial* manner.

[1] Musen, P., "A Modified Hansen's Theory as Applied to the Motion of Artificial Satellites," NASA Technical Note D-492, November 1960.

Consider a term such as A_n cos (iF + jE + kW + lU). Until this term is evaluated we are concerned only with the values of A_n, i, j, k, and l. The coefficient A_n is represented by the first of the two eight-digit floating-point words. The four coefficients of the arguments (i, j, k, and l) are each represented by two digits of the second eight-place floating-point word. The first two digits represent i and are normalized to 00; the next three pairs of digits represent j, k, and l, and are normalized to 50. Thus, the value of i may vary from 0 to 99, while j, k, and l may vary from -49 to +49. A cosine is denoted by a plus sign; a sine by a minus sign, that is, 1 cos (0F + 0E + 0W + 0U) or cos (0) becomes +10000000 + 01, +00505050 + 08. Any constant term can be represented as A_n cos (0). A few additional examples will be helpful (see also Appendix A):

Conventional	Special
1/4 cos (1F + 2E - 3W - 2U)	25000000 + 00, +01524748 + 08
1/4 sin (0F + 1E - 0W + 2U)	25000000 + 00, -00515052 + 08
1/4	25000000 + 00, +00505050 + 08
0	00000000 + 00, +00505050 + 08

The convention of having the first non-zero coefficient of the argument word positive was adopted. Cos(-x) becomes cos(x) and sin(-x) becomes -sin(x). Examples are:

(1/2) cos (0F - 3E + 1W + 0U) becomes (1/2) cos (0F + 3E - 1W + 0U)
and the special representation is 50000000 + 00, + 00534950 + 08

(1/2) sin (0F - 3E + 1W + 0U) becomes -(1/2) sin (0F + 3E - 1W + 0U)
and the special representation is -50000000 + 00 - 00534950 + 08.

The first location address of a series contains the number of terms of the series. A series of n terms would be represented by 2n + 1 words the first of which would be the number n.

THE FOURIER OPERATING PACKAGE

The following series operations are performed by the Fourier Operating Package:

- Multiplication
- Addition and Subtraction
- Differentiation
- Integration
- Bar (Special operation used in the Hansen satellite theory)
- Scalar Multiplication
- Coefficient Extraction
- Series Evaluation

Multiplication

Multiplication of two series, where the terms are of the general form described earlier and the values of F, E, W, and U are not used until the final numerical evaluation, is according to the conventional trigonometric identities:

$$\begin{aligned} A \cos X \cdot B \cos Y &= (AB/2) \cos (X+Y) + (AB/2) \cos (X-Y) \\ A \cos X \cdot B \sin Y &= (AB/2) \sin (X+Y) - (AB/2) \sin (X-Y) \\ A \sin X \cdot B \cos Y &= (AB/2) \sin (X+Y) + (AB/2) \sin (X-Y) \\ A \sin X \cdot B \sin Y &= (AB/2) \cos (X+Y) + (AB/2) \cos (X-Y). \end{aligned}$$

The Fourier Multiplication routine is composed of three major sections: the multiplier, the collapser, and the arranger.

The Multiplier

Two Fourier series such as

$$A_1A_1^* + A_2A_2^* + A_3A_3^* + \dots + A_nA_n^* \qquad \text{(Series A)}$$

and

$$B_1B_1^* + B_2B_2^* + B_3B_3^* + \dots + B_mB_m^* \qquad \text{(Series B)}$$

which are to be multiplied are arranged in descending order of the absolute values of the coefficients, that is,

$$|A_1| > |A_2| > |A_3| > \dots > |A_n| \text{ and } |B_1| > |B_2| > |B_3| > \dots > |B_m|$$

To facilitate further discussion, we shall denote any term in the A series $A_xA_x^*$, any term in the B series as $B_yB_y^*$, and any term in the resultant series by $C_zC_z^*$, where A_x, B_y and C_z are the coefficient words and A_x^*, B_y^*, and C_z^* are the argument words.

The multiplication of the A series by the B series proceeds as follows: The first term in the A series is multiplied by each term in the B series, then the second term in the A series is multiplied by each term in the B series, and so on until each term in the A series has been multiplied by each term in the B series. For example, $|A_xB_y|$ is compared with some numerical criterion e. If $|A_xB_y| > e$, then $C_zC_z^*$ and $C_{(z+1)}\ C_{(z+1)}^*$ are generated according to the trigonometric formulas already stated. If $|A_xB_y| \leq e$, then the value of y is examined. If $y > 1$ (i.e., B_y is any term other than the first term), A_x is replaced by $A_{(x+1)}$ and $A_{(x+1)}$ is multiplied by B_1. If $y = 1$, the multiplication of the two series is terminated since any further $A_{(x+1)}\ B_y$ will also be less than e. The multiplication process continues until $A_nA_n^*$ has been multiplied by $B_mB_m^*$ unless the numerical criterion or space limitations intervene.

The Collapser

Every multiplication generates two terms of two words each. The purpose of the collapser is to combine like argument terms. Each argument term C_z^* is compared with each other argument term previously generated and stored. If C_z^* equals any other argument term, the corresponding coefficient terms are added. Thus, there is no duplication of terms.

The Arranger

The final step in the multiplication is the arranging of the terms of the series. $|C_1|$ is compared with $|C_2|$, $|C_3|$, etc. If $|C_z| > |C_1|$, then C_1 is replaced by C_z and C_1^* is replaced by C_z^*. The process continues until the terms are arranged, in descending order, according to the absolute value of the coefficients.

Addition and Subtraction

Addition or subtraction of two Fourier series is primarily a process of comparing argument terms and adding the coefficients of like terms. A_1^* is compared successively with B_1^* through B_m^*, A_2^* with B_1^* through B_m^*, etc., until A_n^* has been compared with B_m^*. If $A_x^* = B_y^*$, the sum of the coefficients $(A_x + B_y)$ and the argument term A_x^* are stored, and B_y and B_y^* are replaced by zeros. If A_x^* does not equal any B_y^*, both A_x and A_x^* are stored. After all terms in the A series have been compared with all terms in the B series, the remaining B series terms are stored.

Subtraction is accomplished in like manner after changing the signs of each coefficient term in the B series. The resultant series in each case is processed through the arranger.

Differentiation

Differentiation, in this application, is with respect to the F variable. Thus,

$$\left(\frac{\partial}{\partial F}\right) A \sin (iF + jE + kW + lU) = iA \cos (iF + jE + kW + lU).$$

Example:

$$\left(\frac{\partial}{\partial F}\right) \sin (3F + 2E - 3W + U) = +3 \cos (3F + 2E - 3W + U)$$

and

$\left(\frac{\partial}{\partial F}\right)$[10000000 + 01, - 03524751 + 08 becomes +30000000 + 01, +03524751 + 08.

On completion of the differentiation, the resultant series is processed thru the arranger.

Integration

Integration, in this application, is with respect to E. However, W is also a function of E. Thus,

$$\int A \cos (iF + jE + kW + 1U)dE = \frac{A}{c_1 j + c_2 k} \sin (iF + jE + kW + 1U).$$

Example:

With $c_1 = 1$ and $c_2 = 1$,

$\int$[30000000 + 01, + 01525250 + 08]dE becomes 75000000 + 00, -01525250 + 08.

The resultant integrated series is also processed through the arranger.

Bar Operation

The bar operation is a special function in the Hansen Satellite Theory. It consists of adding the coefficient of the F argument to the coefficient of the E argument and substituting zero for the F coefficient. Thus,

A cos (iF + jE + kW + 1U) after barring becomes A cos (0F + (i + j) E + kW + 1U).

Example:

50000000 + 00, + 02534850 + 08 after barring becomes 50000000 + 00, + 00554850 + 08.

Scalar Multiplication

Scalar multiplication is the multiplication of the coefficient A_n of each term by a constant.

Coefficient Extraction

In the Hansen Satellite Theory it is sometimes necessary to use the coefficient of some term of a Fourier series such as a sine 1F term, cosine 2E term, or the constant term of a series. Let us assume it is necessary to use the constant term. If there is a constant term in that series, it will be the multiplier of the cos (0), or in special form, that A_n word which multiplies 00505050 + 08. We successively compare each argument term in the series with cos (0) and extract that A_n which multiplies the argument term cos (0). If no argument term of the series is cos (0), a normalized zero (10000000 + 00 + 00000000 + 00 + 00505050 + 08), is printed.

Series Evaluation

The numerical values F, E, W, and U are only employed in the Series Evaluation Routine.

To evaluate a Fourier series, the numerical values of i, j, k, and l are multiplied by the numerical values of F, E, W, and U, and the sum iF + jE + kW + lU is determined. The sine or cosine of iF + jE + hW + lU is multiplied by the coefficient A and the terms are added.

CONCLUDING REMARKS

Appendix A is the special representation of a nine term series. Appendix B presents flow charts and Appendix C a listing of instructions for the program packages for multiplication (including the collapser and arranger), addition or subtraction, differentiation, integration, bar operation, scalar multiplication, coefficient extraction, and the evaluation of the final series. Because this program was written in Mystic Code for the IBM 709, an explanation of Mystic Code is given in Appendix D.

The Fourier operating package can be used with any theory that involves representations of functions by Fourier series. It can also be modified to operate with polynomials of the form $X^aY^bZ^cU^d$.

ACKNOWLEDGMENTS

The author is indebted to Messrs. R. G. Kelly and T. P. Gorman for their aid in the construction of the package and for the translation into Mystic Code and to Aileen Marlo' for preparing the flow charts.

Appendix A

Nine Term Series in Standard and Special Form

The following is a nine term series presented in standard and in special form. Note that in the special form, the first location (address) contains the number of terms in the series.

Series in standard representation

.29467121 cos (0)
+.00010496334 cos (0F + 0E + 2W + 0U)
+.00005252596 sin (0F + 1E - 1W + 0U)
+.000019845618 cos (0F + 1E - 2W + 0U)
+.0000066329604 cos (0F + 1E + 2W + 0U)
+.0000020107054 cos (0F + 2E - 2W + 0U)
-.00000036004597 sin (0F + 0E + 1W + 0U)
-.000000055052357 sin (0F + 0E + 3W + 0U)
-.000000031090653 sin (0F + 1E + 1W + 0U)

Series in special representation

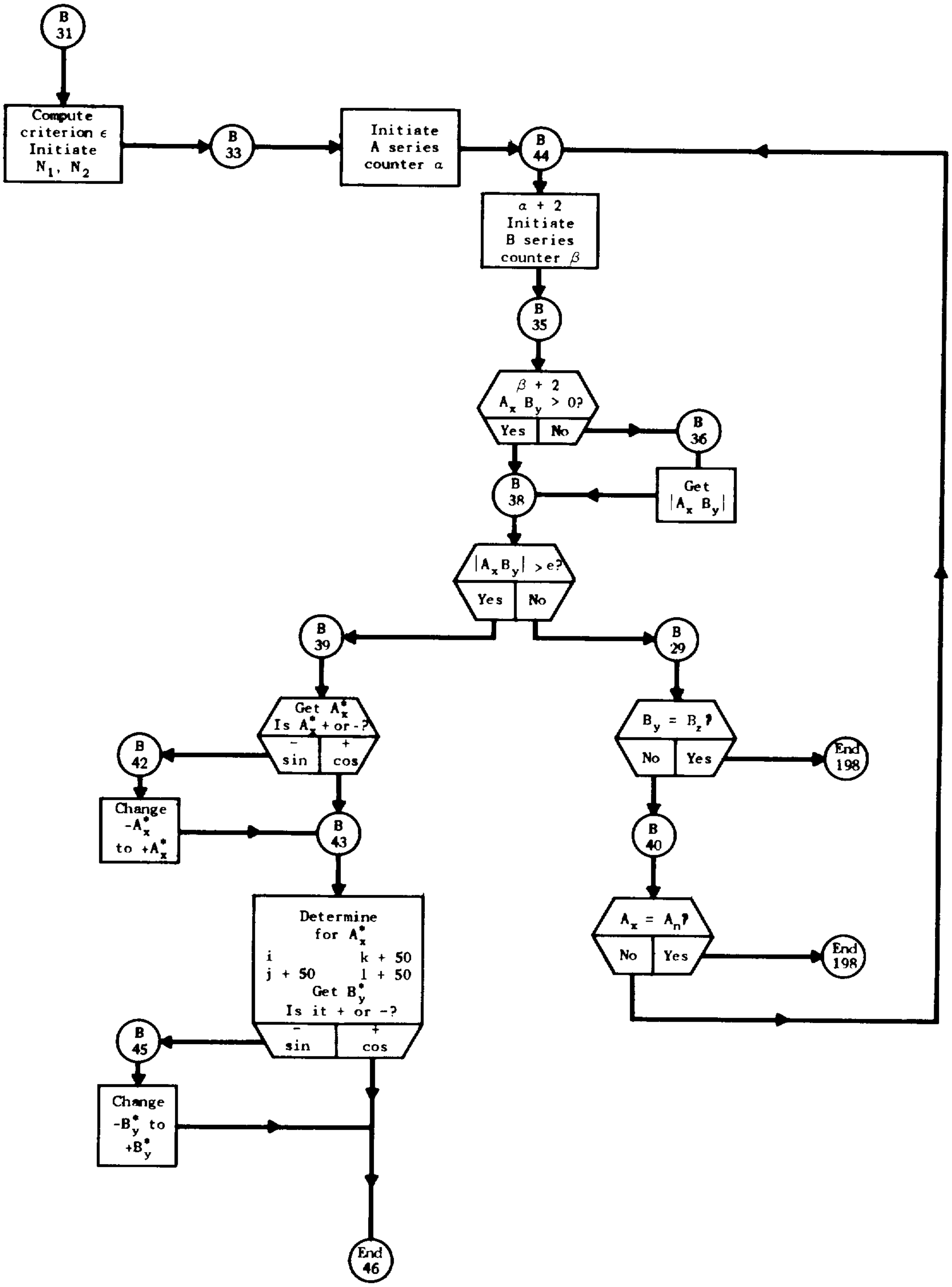
```
 90000000 + 01
+29467127+00, +00505050+08
+10496334-03, +00505250+08
+52525962-04, -00514950+08
+19845618-04, +00514850+08
+66329604-05, +00515250+08
-20107054-05, +00524850+06
-36004597-06, -00505150+08
-55052357-07, -00505350+08
-31090653-07, -00515150+08
```

Appendix B

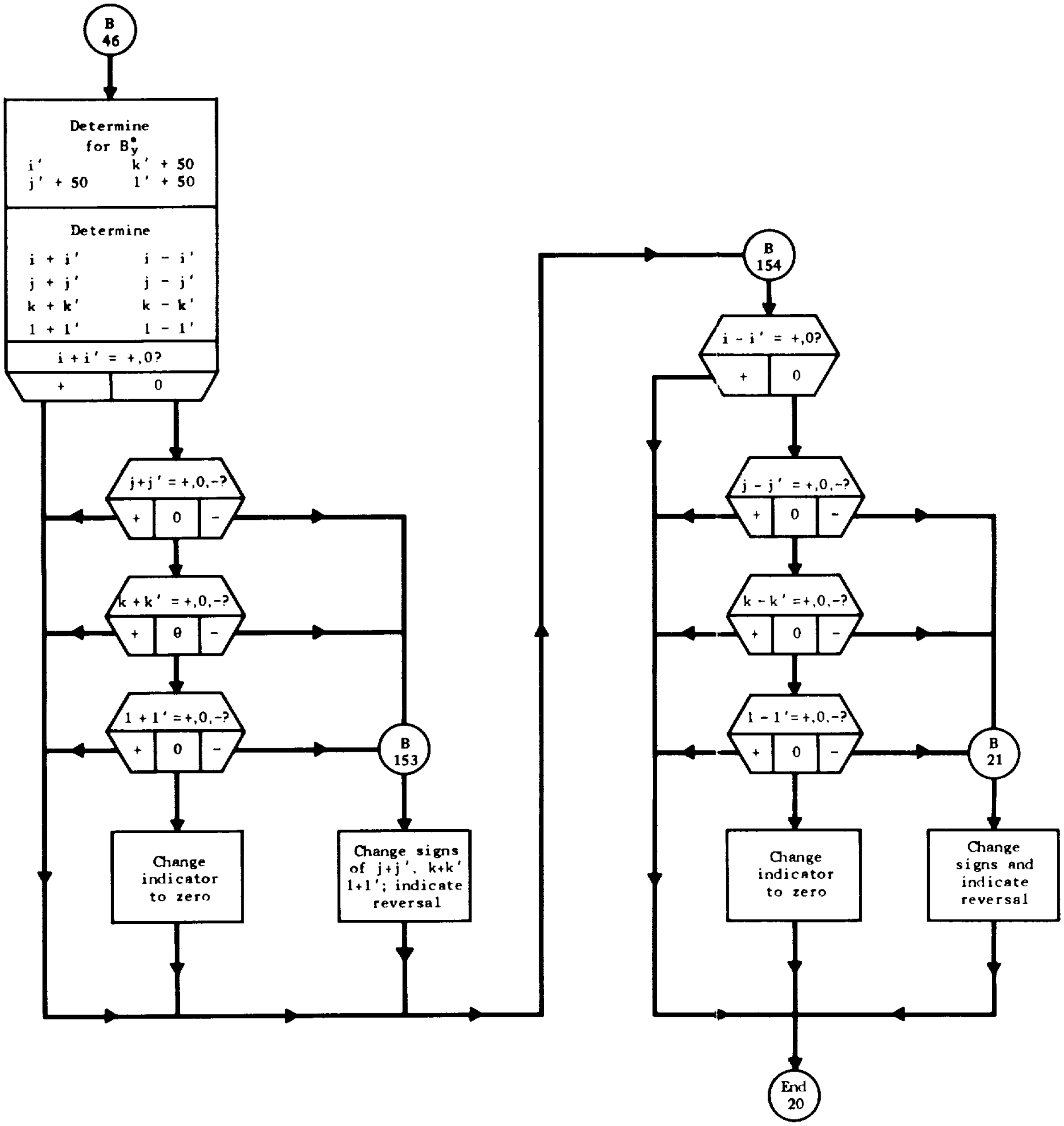
Flow Charts

The following are the flow charts for the operating packages for multiplication (including the collapser and the arranger), addition or subtraction, bar operation, differentiation, integration, and series evaluation.

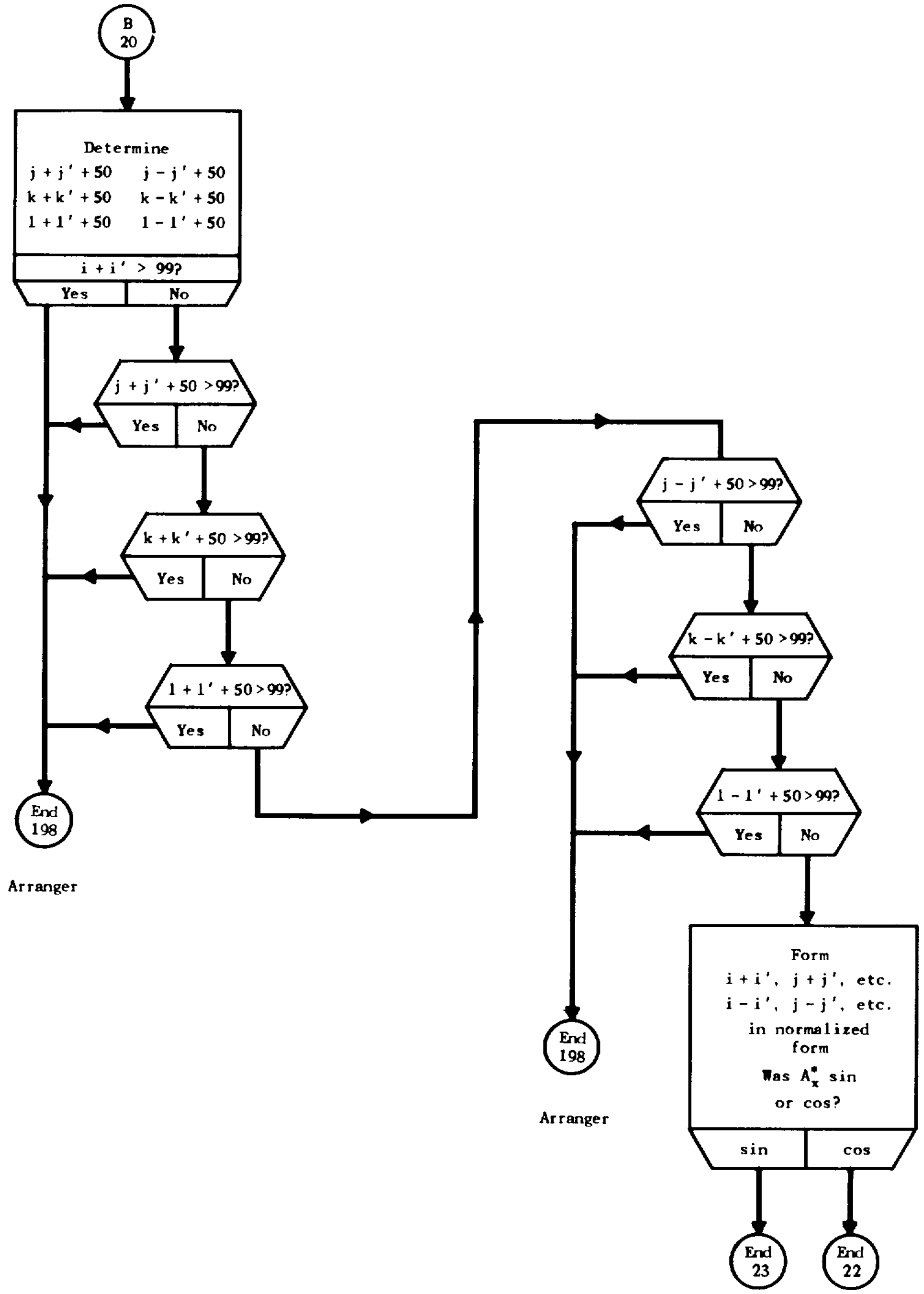
Flow Chart for Multiplication



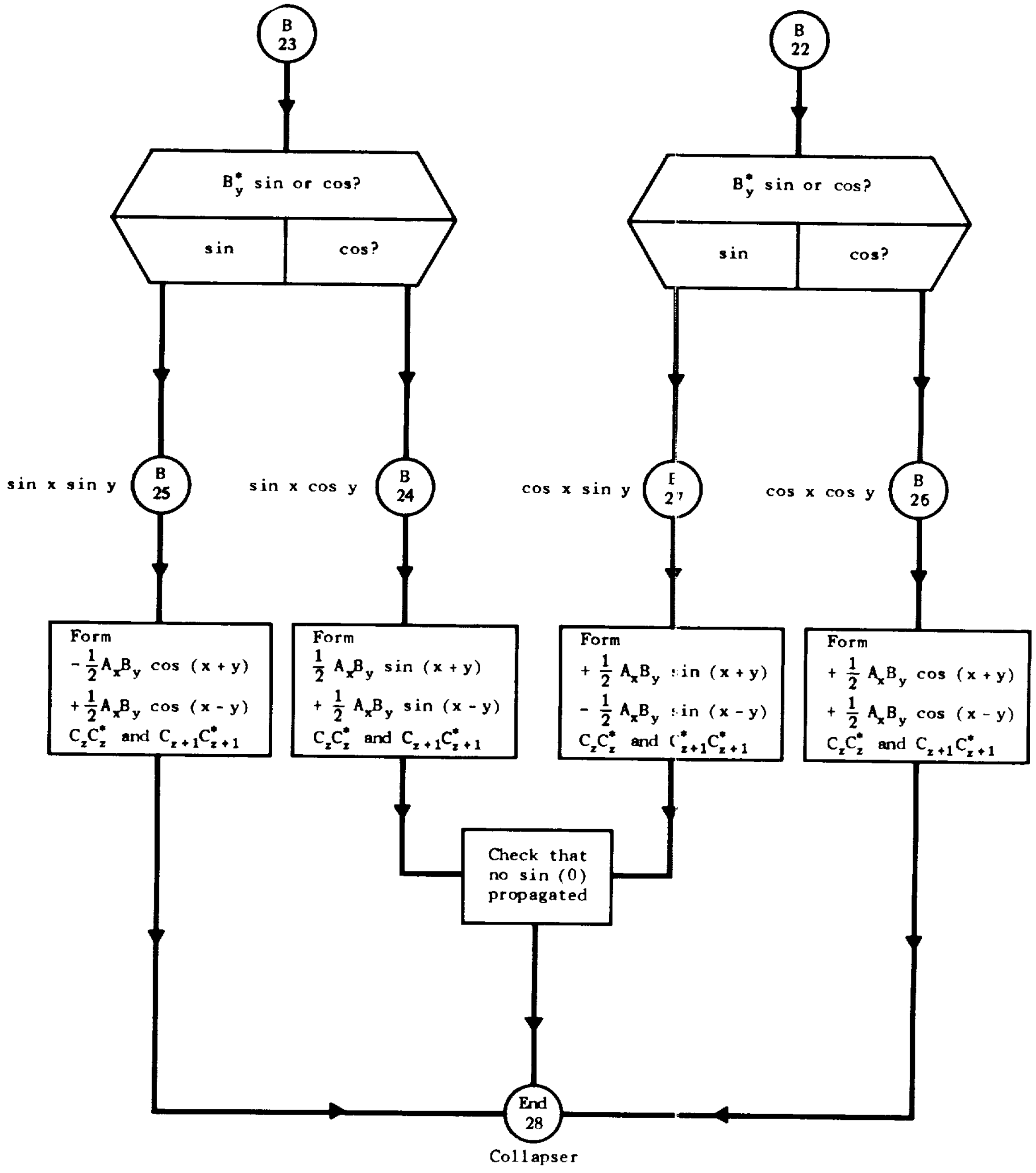
Flow Chart for Multiplication (Continued)



Flow Chart for Multiplication (Continued)



Flow Chart for Multiplication (Continued)


B 23
B_y^* sin or cos?
sin
cos?
B 22
B_y^* sin or cos?
sin
cos?
sin x sin y
B 25
sin x cos y
B 24
cos x sin y
B 27
cos x cos y
B 26
Form
$-\frac{1}{2} A_x B_y$ cos (x + y)
$+\frac{1}{2} A_x B_y$ cos (x - y)
$C_z C_z^*$ and $C_{z+1} C_{z+1}^*$
Form
$\frac{1}{2} A_x B_y$ sin (x + y)
$+ \frac{1}{2} A_x B_y$ sin (x - y)
$C_z C_z^*$ and $C_{z+1} C_{z+1}^*$
Form
$+ \frac{1}{2} A_x B_y$ sin (x + y)
$- \frac{1}{2} A_x B_y$ sin (x - y)
$C_z C_z^*$ and $C_{z+1} C_{z+1}^*$
Form
$+ \frac{1}{2} A_x B_y$ cos (x + y)
$+ \frac{1}{2} A_x B_y$ cos (x - y)
$C_z C_z^*$ and $C_{z+1} C_{z+1}^*$
Check that no sin (0) propagated
End 28
Collapser

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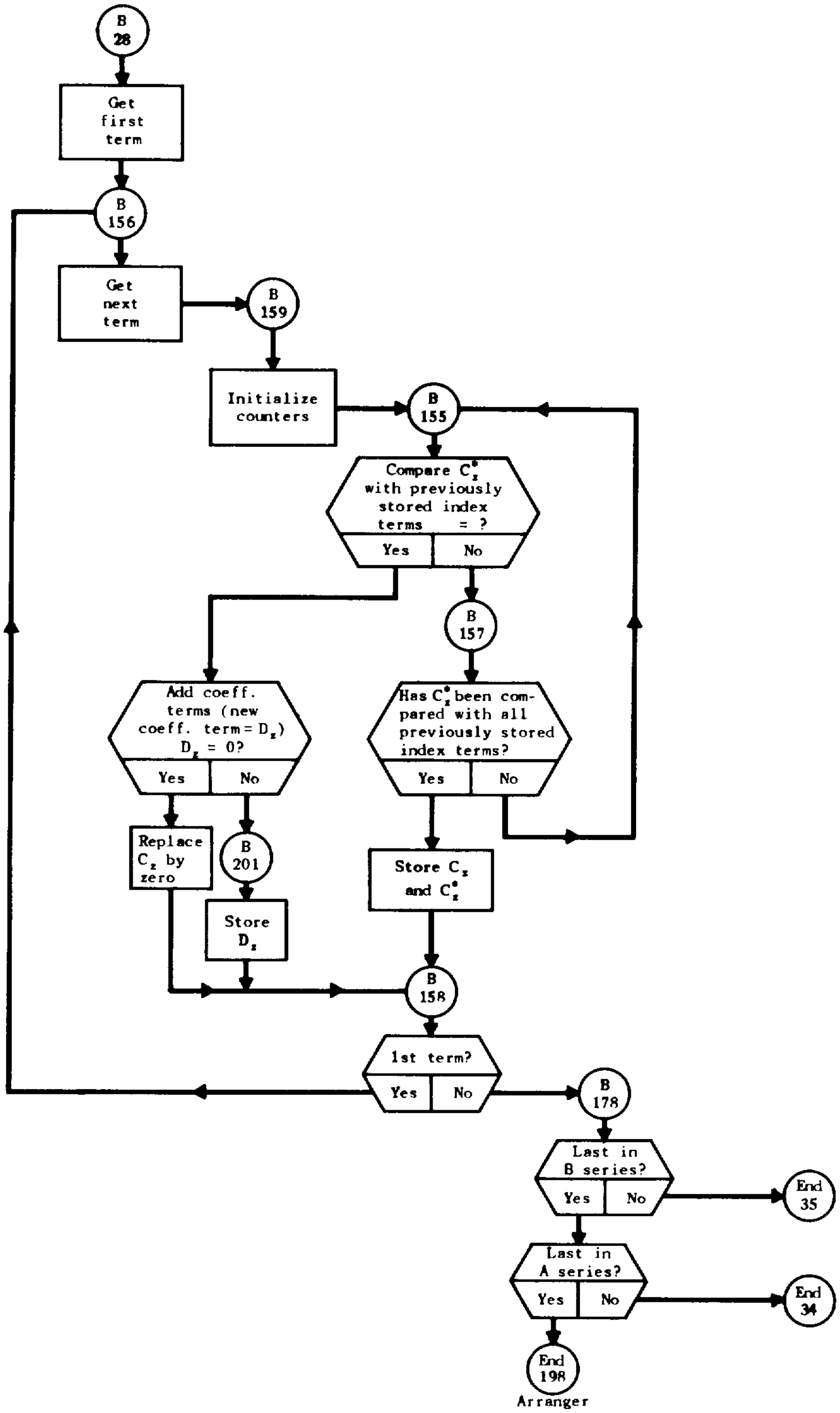
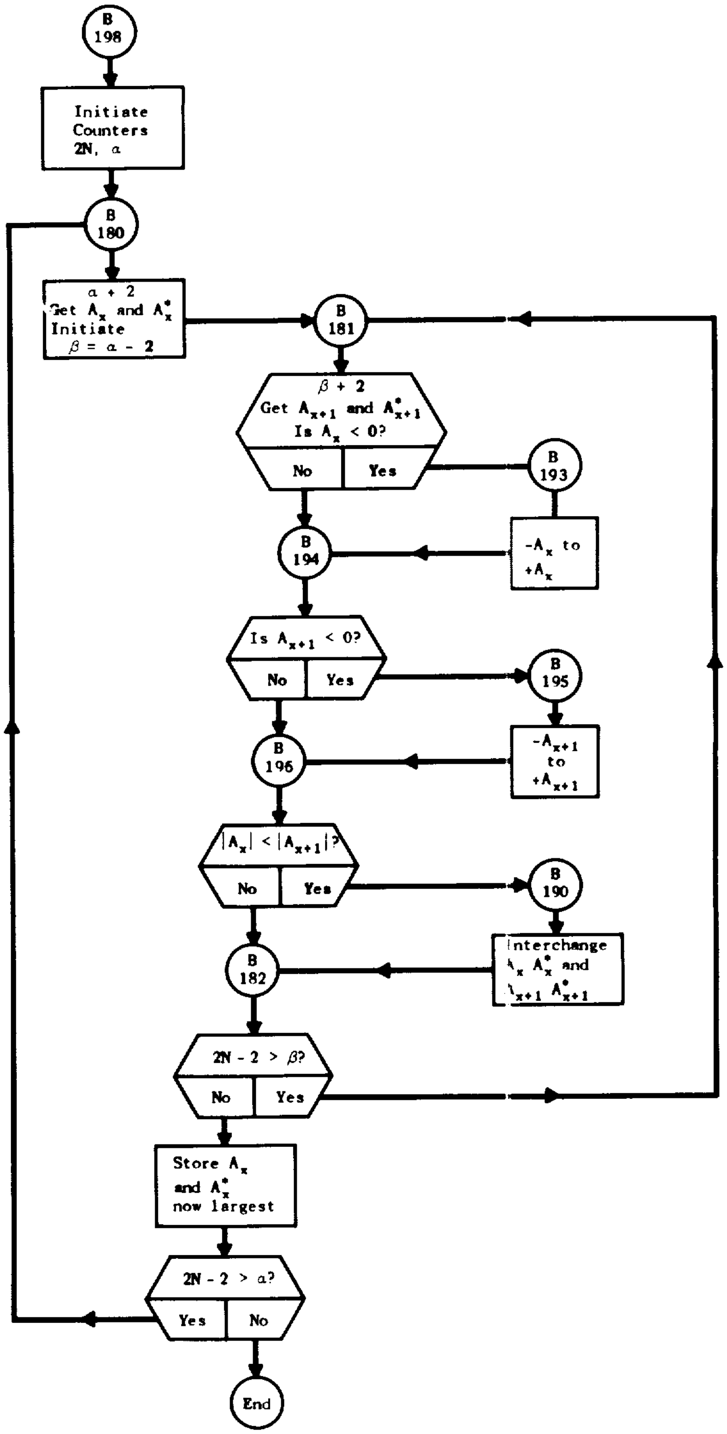
Flow Chart for Multiplication (Continued)

Collapser



Flow Chart for Multiplication (Continued)

Arranger


B 198
Initiate Counters 2N, α
B 180
$\alpha + 2$ Get A_x and A_x^* Initiate $\beta = \alpha - 2$
B 181
$\beta + 2$ Get A_{x+1} and A_{x+1}^* Is $A_x < 0$?
No
Yes
B 193
$-A_x$ to $+A_x$
B 194
Is $A_{x+1} < 0$?
No
Yes
B 195
$-A_{x+1}$ to $+A_{x+1}$
B 196
$|A_x| < |A_{x+1}|$?
No
Yes
B 190
Interchange A_x A_x^* and A_{x+1} A_{x+1}^*
B 182
$2N - 2 > \beta$?
No
Yes
Store A_x and A_x^* now largest
$2N - 2 > \alpha$?
Yes
No
End

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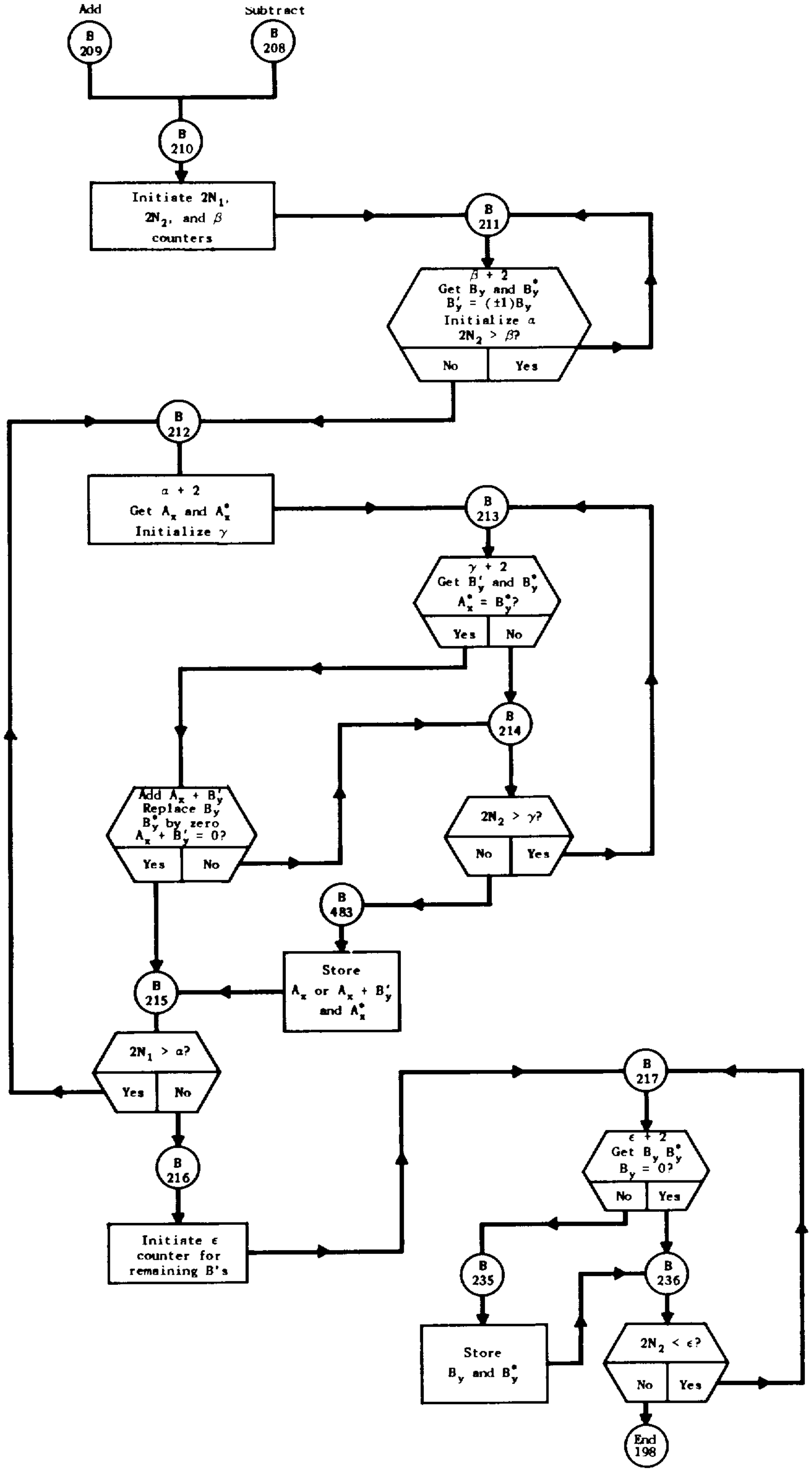
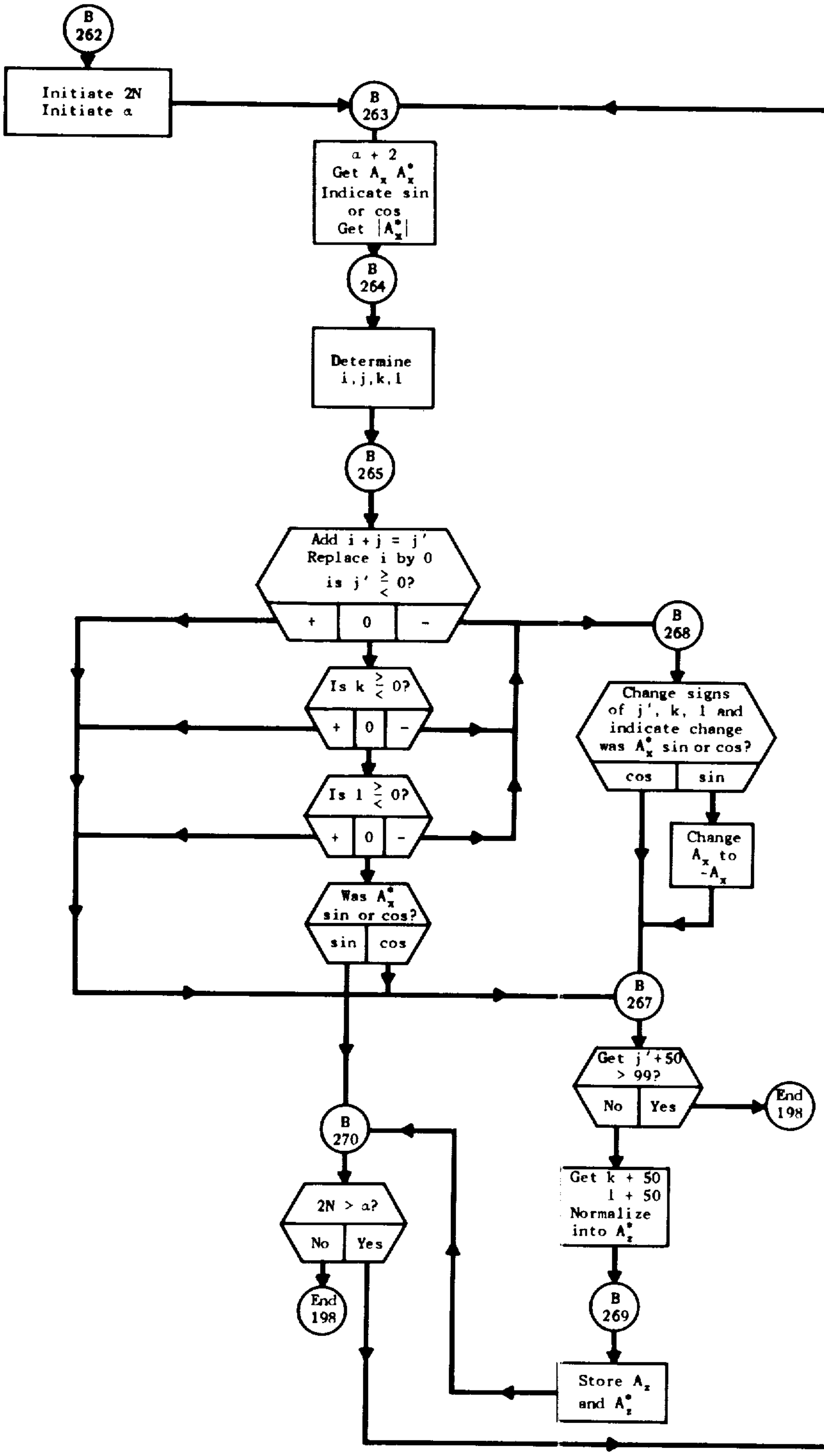
Flow Chart for Addition or Subtraction



Flow Chart for Bar Operation



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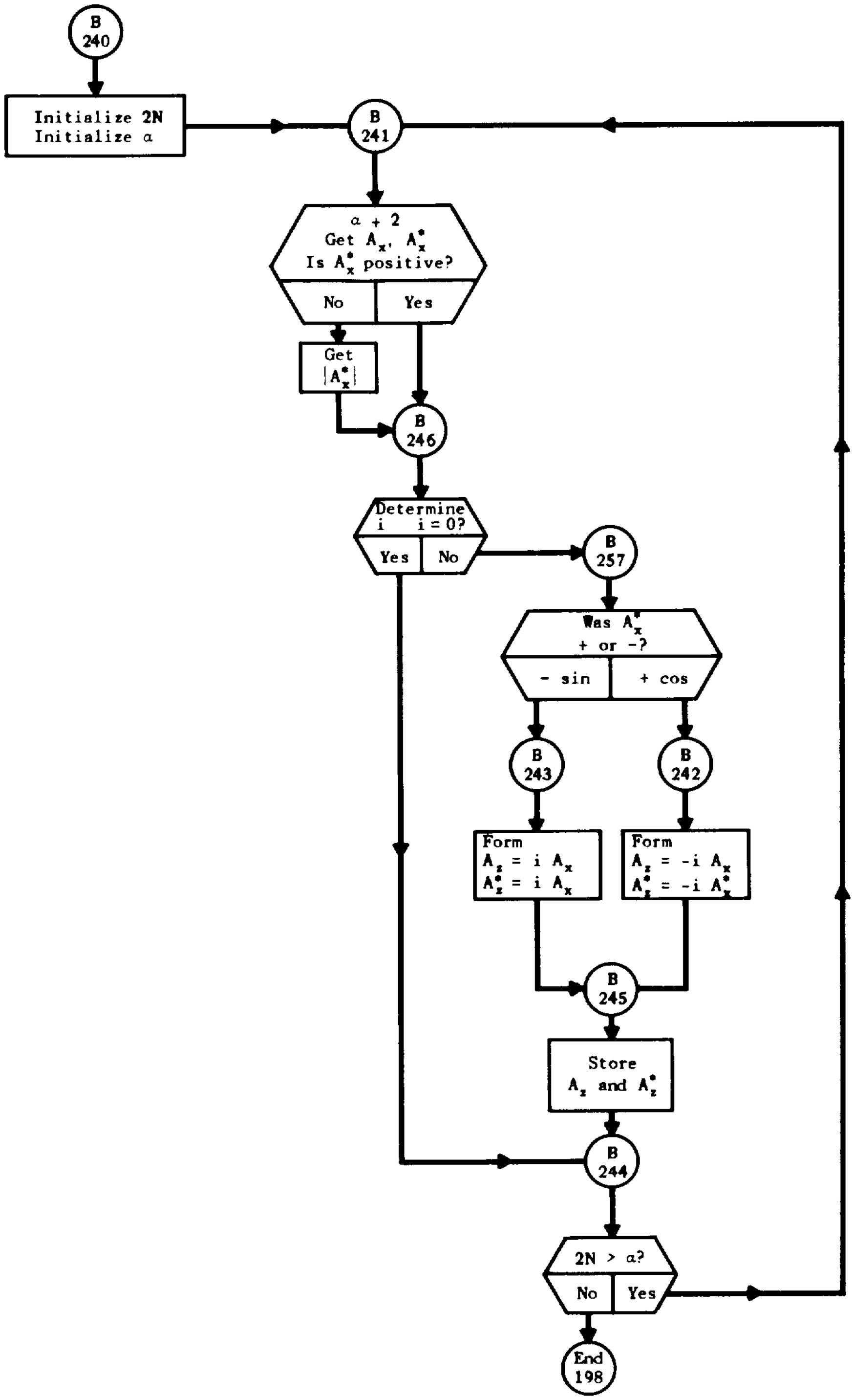
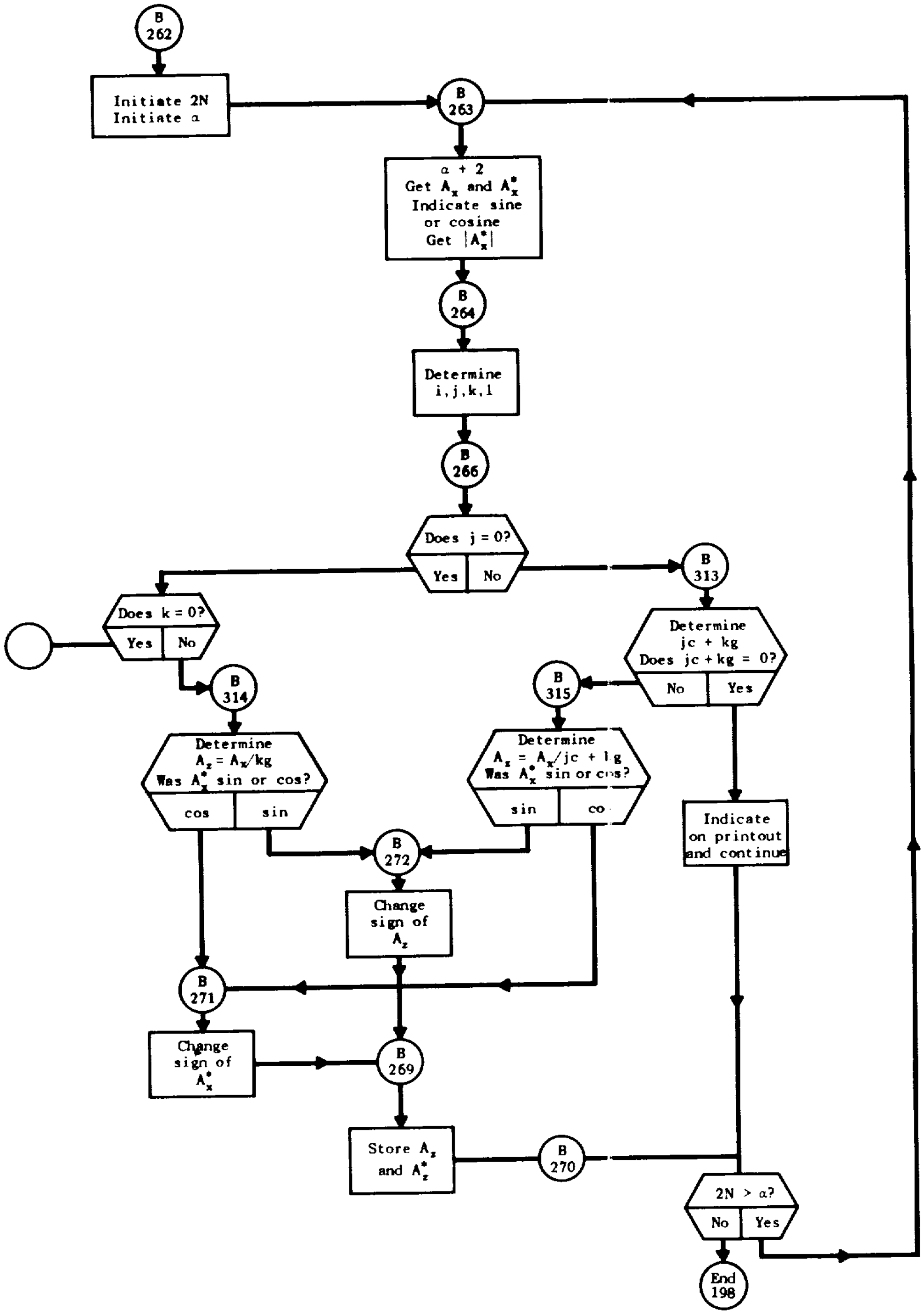
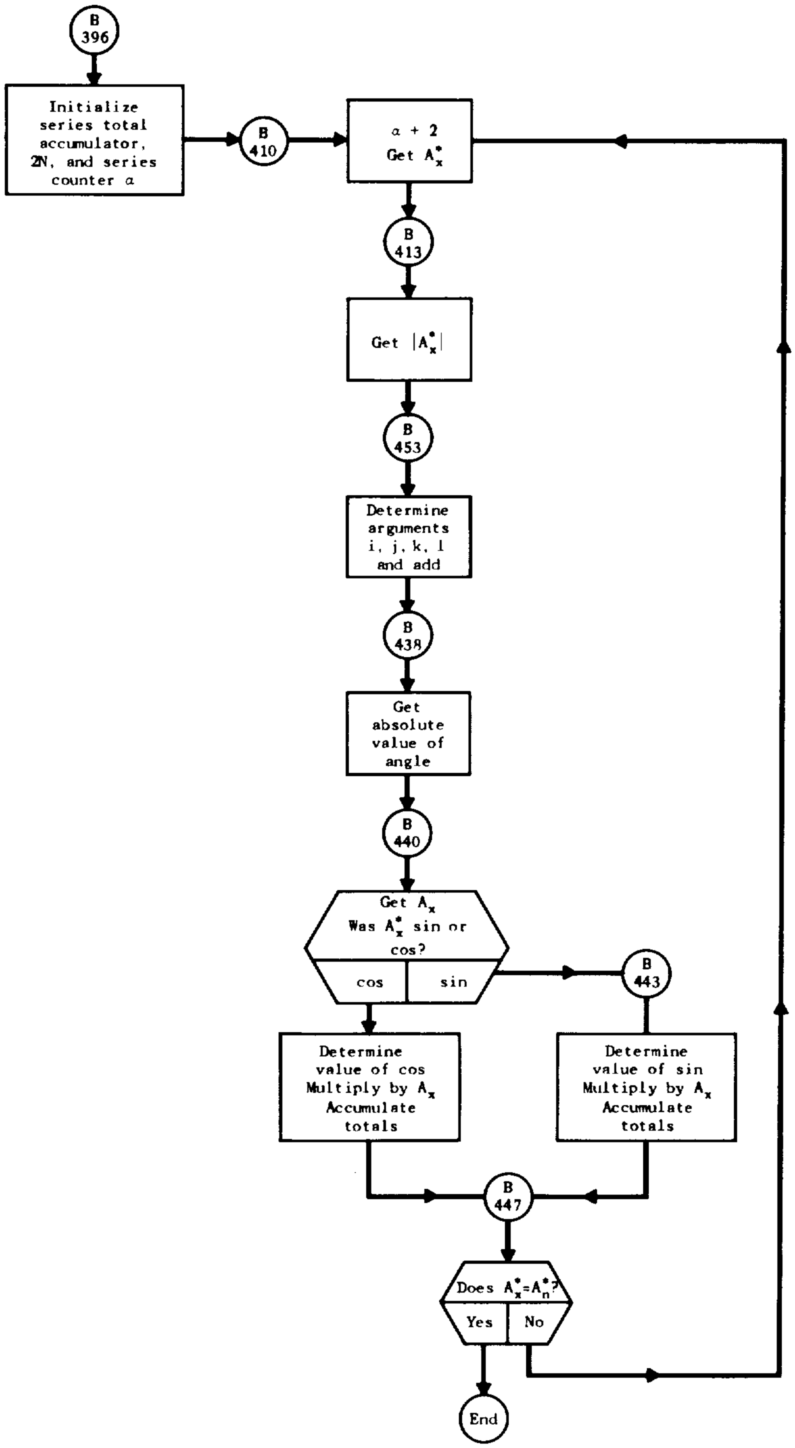
Flow Chart for Differentiation



Flow Chart for Integration



Flow Chart for Series Evaluation


B 396
Initialize series total accumulator, 2N, and series counter α
B 410
α + 2
Get A_x^*
B 413
Get $|A_x^*|$
B 453
Determine arguments i, j, k, l and add
B 438
Get absolute value of angle
B 440
Get A_x
Was A_x^* sin or cos?
cos
sin
B 443
Determine value of cos Multiply by A_x Accumulate totals
Determine value of sin Multiply by A_x Accumulate totals
B 447
Does $A_x^*=A_n^*$?
Yes
No
End

Appendix C

Listing of Instructions

The following is a listing of instructions for multiplication (including the collapser and the arranger), addition or subtraction, differentiation, integration, bar operation, scalar multiplication, and coefficient extraction.

The square root instructions are for standard number representations and therefore have not been discussed in the report.

```
                                                                              PAGE001
                              K=   00000

      HANSEN SATELLITE THE⊙RY MLC                                           001
          ADAPTER PACKAGE                                                    002
  ⊙ 21750                              ⊙RIGIN CARD                           003
  K 00000                                                                    004
  K 00050                                                                    005
 *B 00001                                  SQUARE R⊙⊙T FUNCTI⊙N              006
  V 00005 +00000000+00                                                       007
  V 00007  10000000 01                                                       008
  V 00010  20000000-07                                                       009
  G 00003 00001 00003                                                        010
  C 00003 00005 00006                                                        011
  H 00001 00004 00005                                                        012
  E 00002                                                                    013
 *B 00006                                                                    014
  A 00008 00007 00007                                                        015
  R 00009 00007                                                              016
  S 00011 00007 00010                                                        017
  C 00007 00003 00012                                                        018
  R 00009 00003                                                              019
 *B 00012                                                                    020
  D 00013 00003 00009                                                        021
  A 00014 00009 00013                                                        022
  D 00015 00014 00008                                                        023
  D 00016 00015 00009                                                        024
  R 00009 00015                                                              025
  C 00011 00016 00012                                                        026
  H 00001 00004 00009                                                        027
  F 00002                                                                    028
  K 00000                                                                    029
  K 00070                                                                    030
 *B 00001                                  SIN C⊙SINE FUNCTI⊙N               031
  V 00009  17000000-04                                                       032
  V 00010  10000000 01                                                       033
  V 00011  67108864 08                                                       034
  V 00012  15707963 01                                                       035
  V 00013 -64596371 00                                                       036
  V 00014  79689679-01                                                       037
  V 00015 -46737660-02                                                       038
  V 00016  15148400-03                                                       039
  V 00018 +00000000+00                                                       040
  V 00019 +62831853+01                                                       041
  G 00003 00001 00003                                                        042
```

```
                                              K=    00070                                                  PAGE002

  R 00020 00010                                                                                   043
  C 00003 00018 00021                                                                             044
  S 00020 00018 00020                                                                             045
  S 00003 00018 00003                                                                             046
 *B 00021                                                                                         047
  D 00022 00003 00019                                                                             048
  A 00022 00022 00011                                                                             049
  S 00022 00022 00011                                                                             050
  M 00022 00022 00019                                                                             051
  S 00003 00003 00022                                                                             052
  M 00003 00003 00020                                                                             053
  S 00020 00018 00012                                                                             054
  R 00023 00010                                                                                   055
 *B 00024                                                                                         056
  I 00025 +31415926+01                                                                            057
  C 00003 00012 00026                                                                             058
  S 00025 00018 00025                                                                             059
  C 00020 00003 00026                                                                             060
  D 00003 00003 00012                                                                             061
  M 00027 00003 00003                                                                             062
  M 00028 00016 00027                                                                             063
  A 00028 00028 00015                                                                             064
  M 00028 00028 00027                                                                             065
  A 00028 00028 00014                                                                             066
  M 00028 00028 00027                                                                             067
  A 00028 00028 00013                                                                             068
  M 00028 00028 00027                                                                             069
  A 00028 00028 00012                                                                             070
  M 00028 00028 00023                                                                             071
  M 00003 00028 00003                                                                             072
  H 00001 00004 00003                                                                             073
  F 00002                                                                                         074
 *B 00026                                                                                         075
  S 00003 00003 00025                                                                             076
  S 00023 00018 00023                                                                             077
  F 00024                                                                                         078
 *B 00005                                                                                         079
  G 00003 00005 00007                                                                             080
  S 00017 00012 00003                                                                             081
  F 00017 00001 00017                                                                             082
  H 00005 00008 00017                                                                             083
  F 00006                                                                                         084
```

```
                                      K=   00070                                     PAGE003

 K 00000                                                                             085
 K 00100                                                                             086
*B 00001                               FØURIER SERIES MØVE                           087
 G 00005 00001 00003                                                                 088
 A 00006 00005 00005                                                                 089
 A 00006 00006 00003                                                                 090
 H 00001 00004 00005                                                                 091
*B 00007                                                                             092
 A 00003 00003 00008                                                                 093
 A 00004 00004 00008                                                                 094
 G 00005 00001 00003                                                                 095
 H 00001 00004 00005                                                                 096
 C 00006 00003 00007                                                                 097
 F 00002                                                                             098
 V 00008 +10000000+01                                                                099
 K 00010                                                                             100
*B 00001                               FØURIER ADDITIØN (11)                         101
 R 00080 00299                                                                       102
 R 00072 00002                                                                       103
 S 00073 00003 00005                                                                 104
 S 00074 00004 00005                                                                 105
 E 00071                                                                             106
 V 00005 +70000000+02                                                                107
 K 00005                                                                             108
*B 00001                               FØURIER SUBTRACTIØN (16)                      109
 R 00075 00293                                                                       110
 R 00067 00002                                                                       111
 S 00068 00003 00005                                                                 112
 S 00069 00004 00005                                                                 113
 F 00066                                                                             114
 V 00005 +65000000+02                                                                115
 K 00005                                                                             116
*B 00001                               FØURIER MULTIPLICATIØN (21)                   117
 R 00070 00111                                                                       118
 R 00062 00002                                                                       119
 S 00063 00003 00005                                                                 120
 S 00064 00004 00005                                                                 121
 F 00061                                                                             122
 V 00005 +60000000+02                                                                123
 K 00005                                                                             124
*B 00001                               FØURIER K-MULTIPLICATIØN (26)                 125
 R 00057 00002                                                                       126
```

```
                                                              PAGE004
                          K=   00125

 G 00414 00001 00003                                            127
 S 00059 00004 00005                                            128
 C 00414 00067 00405 00405                                      129
 H 00001 00004 00066                                            130
 H 00002 00004 00067                                            131
 H 00003 00004 00069                                            132
 F 00002                                                        133
 V 00005 +55000000+02                                           134
 K 00005                                                        135
*B 00001                FOURIFR TERM FXTRACTI⊙N (31)            136
 R 00052 00002                                                  137
 G 00419 00001 00003                                            138
 S 00054 00004 00005                                            139
 F 00415                                                        140
 V 00005 +50000000+02                                           141
 K 00005                                                        142
*B 00001                F⊙URIER DIFFERENTIATI⊙N (36)            143
 R 00055 00305                                                  144
 R 00047 00002                                                  145
 S 00048 00003 00005                                            146
 S 00049 00004 00005                                            147
 F 00046                                                        148
 V 00005 +45000000+02                                           149
 K 00005                                                        150
*B 00001                F⊙URIER INTEGRATI⊙N (41)                151
 R 00042 00002                                                  152
 R 00050 00321                                                  153
 S 00043 00003 00005                                            154
 S 00044 00004 00005                                            155
 F 00041                                                        156
 V 00005 +40000000+02                                           157
 K 00005                                                        158
*B 00001                F⊙URIER ARGUMENT REPLACEMENT (46)       159
 R 00037 00002                                                  160
 S 00038 00003 00005                                            161
 S 00039 00004 00005                                            162
 R 00045 00315                                                  163
 F 00036                                                        164
 V 00005 +35000000+02                                           165
 K 00035                                                        166
*B 00001                F⊙URIFR PKG ADAPTFR                     167
 A 00013 00015 00015                                            168
```

```
                                        K=    00180                                         PAGF005

 G 00005 00001 00003                                                                   169
 R 00720 00005                          PATS ADAPTER                                   170
 A 00005 00005 00005                                                                   171
 A 00005 00005 00003                                                                   172
 R 00006 00012                                                                         173
*B 00007                                                                               174
 A 00006 00006 00011                                                                   175
 C 00006 00013 00016                                                                   176
 A 00003 00003 00011                                                                   177
 G 00008 00001 00003                                                                   178
 H 00720 00006 00008                    PATS ADAPTER                                   179
 C 00005 00003 00007                                                                   180
 A 00006 00013 00013                                                                   181
 I 00008 -10000000+01                                                                  182
*B 00018                                                                               183
 A 00008 00008 00011                                                                   184
 H 00920 00008 00012                    PATS ADAPTER                                   185
 C 00006 00008 00018                                                                   186
 F 00010                                                                               187
*B 00519                                                                               188
 A 00005 00004 00920                                                                   189
 A 00005 00005 00920                                                                   190
 R 00006 00012                                                                         191
 H 00001 00004 00920                                                                   192
 C 00920 00012 00009 00009              PATS ADAPTER                                   193
 H 00001 00004 00011                                                                   194
 H 00002 00004 00012                                                                   195
 H 00003 00004 00014                                                                   196
 F 00002                                                                               197
*B 00009                                                                               198
 A 00004 00004 00011                                                                   199
 A 00006 00006 00011                                                                   200
 C 00006 00013 00017                                                                   201
 G 00008 00920 00006                    PATS ADAPTER                                   202
 H 00001 00004 00008                                                                   203
 C 00005 00004 00009                                                                   204
 F 00002                                                                               205
 V 00011 +10000000+01                                                                  206
 V 00012 +00000000+00                                                                  207
 V 00014 +00505050+08                                                                  208
 V 00015 +98000000+02                                                                  209
*B 00016                                                                               210
```

```
                               K=    00180
 R 00920 00015                      PATS ADAPTFR                                     211
 F 00010                                                                              212
*B 00017                                                                              213
 S 00004 00004 00006                                                                  214
 H 00001 00004 00015                                                                  215
 F 00002                                                                              216
 K 00020                                                                              217
 V 00006 +00000000+00                                                                 218
 V 00007 +10000000+01                                                                 219
 V 00008 -10000000+01                                                                 220
 V 00009 +20000000+01                                                                 221
 V 00010 -20000000+01                                                                 222
 V 00011 +50000000+00                                                                 223
 V 00012 +67108864+08                                                                 224
 V 00013 +10000000+07                                                                 225
 V 00014 +10000000+05                                                                 226
 V 00015 +10000000+03                                                                 227
 V 00016 +10000000-07                                                                 228
 V 00016 +10000000-10                   CRITERION FOR DROPPING TERMS                  229
 V 00016 +10000000-12                                                                 230
 V 00017 +50000000+02                                                                 231
 V 00018 +40000000+01                                                                 232
 V 00019 +19200000+03                    (19.=     192                                233
*B 00031                                                                              234
 I 00030 -20000000+01                                                                 235
 A 00030 00030 00009                                                                  236
 G 00049 00500 00030                N*1= NO OF TERMS IN A SERIES                      237
 G 00050 00700 00030                N SUB 2                                           238
 G 00051 00501 00030                A*1                                               239
 G 00052 00701 00030                B SUB 1                                           240
 M 00053 00051 00052                                                                  241
 M 00054 00053 00016                                                                  242
 P 00054 00016                                                                        243
 C 00006 00054 00032 00033                                                            244
 F 00033                                                                              245
*B 00032                                                                              246
 S 00055 00006 00054                                                                  247
*B 00033                                                                              248
 R 00055 00054                                                                        249
 I 00056 -20000000+01                                                                 250
*B 00034                                                                              251
 A 00056 00056 00009                                                                  252
```

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                                                                                        PAGE007
                                    K=    00200

 I 00057 -20000000+01
*B 00035
 A 00057 00057 00009
 G 00058 00501 00056              A*X
 G 00059 00701 00057              B
 M 00060 00058 00059
 C 00006 00060 00036 00037
*B 00036
 S 00061 00006 00060
 F 00038
*B 00037
 R 00061 00060
*B 00038
 C 00055 00061 00029 00039
*B 00029
 C 00057 00006 00040 00198
 F 00198
*B 00040
 M 00047 00049 00009
 S 00047 00047 00009
 C 00047 00056 00034
 F 00198
 V 00140 +00000000+00
 V 00141 -40000000+01
*B 00039
 A 00140 00140 00009
 A 00141 00141 00018
 G 00062 00502 00056              A*
 C 00062 00006 00041 00042
*B 00041
 R 00063 00007
 R 00064 00062
 F 00043
*B 00042
 R 00063 00008
 S 00064 00006 00062
*B 00043
 D 00065 00064 00013
 A 00066 00065 00012
 S 00067 00066 00012
 M 00068 00067 00013
 S 00069 00064 00068
```

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                                          K=   00200                                              PAGE008

 D 00070 00069 00014                                                                        295
 A 00071 00070 00012                                                                        296
 S 00072 00071 00012                                                                        297
 M 00073 00072 00014                                                                        298
 S 00074 00069 00073                                                                        299
 D 00075 00074 00015                                                                        300
 A 00076 00075 00012                                                                        301
 S 00077 00076 00012                                                                        302
 M 00078 00077 00015                                                                        303
 S 00079 00074 00078                                                                        304
 A 00080 00079 00012                                                                        305
 S 00081 00080 00012                                                                        306
 G 00082 00702 00057                          B*                                            307
 C 00082 00006 00044 00045                                                                  308
*B 00044                                                                                    309
 R 00083 00007                                                                              310
 R 00084 00082                                                                              311
 F 00046                                                                                    312
*B 00045                                                                                    313
 R 00083 00008                                                                              314
 S 00084 00006 00082                                                                        315
*B 00046                                                                                    316
 D 00085 00084 00013                                                                        317
 A 00086 00085 00012                                                                        318
 S 00087 00086 00012                                                                        319
 M 00088 00087 00013                                                                        320
 S 00089 00084 00088                                                                        321
 D 00090 00089 00014                                                                        322
 A 00091 00090 00012                                                                        323
 S 00092 00091 00012                                                                        324
 M 00093 00092 00014                                                                        325
 S 00094 00089 00093                                                                        326
 D 00095 00094 00015                                                                        327
 A 00096 00095 00012                                                                        328
 S 00097 00096 00012                                                                        329
 M 00098 00097 00015                                                                        330
 S 00099 00094 00098                                                                        331
 A 00100 00099 00012                                                                        332
 S 00101 00100 00012                                                                        333
 S 00102 00072 00017                                                                        334
 S 00103 00077 00017                                                                        335
 S 00104 00081 00017                                                                        336
```

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                                                                            PAGE009
                                 K=    00200

  S 00105 00092 00017                                                   337
  S 00106 00097 00017                                                   338
  S 00107 00101 00017                                                   339
  A 00108 00102 00105                                                   340
  A 00109 00103 00106                                                   341
  A 00110 00104 00107                                                   342
  S 00111 00102 00105                                                   343
  S 00112 00103 00106                                                   344
  S 00113 00104 00107                                                   345
  A 00114 00067 00087                                                   346
  R 00160 00007                                                         347
  R 00200 00007                                                         348
  C 00114 00006 00154 00154                                             349
  C 00108 00006 00154 00153                                             350
  C 00109 00006 00154 00153                                             351
  C 00110 00006 00154 00153                                             352
  R 00200 00006                                                         353
  F 00154                                                               354
 *B 00153                                                               355
  S 00108 00006 00108                                                   356
  S 00109 00006 00109                                                   357
  S 00110 00006 00110                                                   358
  R 00160 00008                                                         359
 *B 00154                                                               360
  S 00115 00067 00087                                                   361
  R 00116 00007                                                         362
  R 00372 00007                                                         363
  C 00115 00006 00020 00021                                             364
  C 00111 00006 00020 00021                                             365
  C 00112 00006 00020 00021                                             366
  C 00113 00006 00020 00021                                             367
  R 00372 00006                                                         368
  F 00020                                                               369
 *B 00021                                                               370
  S 00111 00006 00111                                                   371
  S 00112 00006 00112                                                   372
  S 00113 00006 00113                                                   373
  S 00115 00006 00115                                                   374
  R 00116 00008                                                         375
 *B 00020                                                               376
  A 00117 00108 00017                                                   377
  A 00118 00109 00017                                                   378
```

```
                                      K=   00200

 A 00119 00110 00017                                                                 379
 A 00120 00111 00017                                                                 380
 A 00121 00112 00017                                                                 381
 A 00122 00113 00017                                                                 382
 V 00495 +99000000+02
 C 00114 00495 00198                     I+I GREATER THAN 99 END
 C 00117 00495 00198                     J+J+50 GREATER THAN 99 END
 C 00118 00495 00198                     K+K+50 GREATER THAN 99 END
 C 00119 00495 00198                     L+L+50 GREATER THAN 99 END
 C 00120 00495 00198                     J-J+50 GREATER THAN 99 END
 C 00121 00495 00198                     K-K+50 GREATER THAN 99 END
 C 00122 00495 00198                     L-L+50 GREATER THAN 99 END
 C 00007 00117 00198                     J+J+50 LESS THAN 1 END
 C 00007 00118 00198                     K+K+50 LESS THAN 1 END
 C 00007 00119 00198                     L+L+50 LESS THAN 1 END
 C 00007 00120 00198                     J-J+50 LESS THAN 1 END
 C 00007 00121 00198                     K-K+50 LESS THAN 1 END
 C 00007 00122 00198                     L-L+50 LESS THAN 1 END
 M 00123 00114 00013                                                                 383
 M 00124 00117 00014                                                                 384
 M 00125 00118 00015                                                                 385
 A 00126 00125 00119                                                                 386
 A 00127 00126 00124                                                                 387
 A 00128 00127 00123                                                                 388
 M 00129 00115 00013                                                                 389
 M 00130 00120 00014                                                                 390
 M 00131 00121 00015                                                                 391
 A 00132 00131 00122                                                                 392
 A 00133 00132 00130                                                                 393
 A 00134 00133 00129                                                                 394
 C 00063 00006 00022 00023                                                           395
 F 00198                                                                             396
*B 00023                                                                             397
 C 00083 00006 00024 00025                                                           398
 F 00198                                                                             399
*B 00025                                                                             400
 R 00135 00060                                                                       401
 M 00136 00135 00011                                                                 402
 R 00137 00128                                                                       403
 R 00138 00136                                                                       404
 R 00139 00134                                                                       405
 S 00136 00006 00136                                                                 406
```

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                                                                                PAGE011
                           K=    00200

 F 00028                                                                     407
*B 00024                                                                     408
 R 00135 00060                                                               409
 M 00136 00135 00011                                                         410
 S 00137 00006 00128                                                         411
 R 00138 00136                                                               412
 S 00139 00006 00134                                                         413
 M 00138 00138 00116                                                         414
 M 00136 00136 00160                                                         415
 M 00136 00136 00200                                                         416
 M 00138 00138 00372                                                         417
 F 00028                                                                     418
*B 00022                                                                     419
 C 00083 00006 00026 00027                                                   420
 F 00198                                                                     421
*B 00026                                                                     422
 R 00135 00060                                                               423
 M 00136 00135 00011                                                         424
 R 00137 00128                                                               425
 R 00138 00136                                                               426
 R 00139 00134                                                               427
 F 00028                                                                     428
*B 00027                                                                     429
 R 00135 00060                                                               430
 M 00136 00135 00011                                                         431
 S 00137 00006 00128                                                         432
 S 00138 00006 00136                                                         433
 S 00139 00006 00134                                                         434
 M 00138 00138 00116                                                         435
 M 00136 00136 00160                                                         436
 M 00136 00136 00200                                                         437
 M 00138 00138 00372                                                         438
*B 00028                                                                     439
 R 00161 00136                                                               440
 R 00162 00137                                                               441
 F 00159                                                                     442
*B 00156                                                                     443
 R 00161 00138                                                               444
 R 00162 00139                                                               445
*B 00159                                                                     446
 I 00164 +00000000+00                                                        447
 I 00165 -10000000+01                                                        448
```

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                                   K=    00200

 C 00161 00006 00155 00155                                                          449
 F 00158                                                                            450
*B 00155                                                                            451
 A 00164 00164 00009                                                                452
 G 00166 00900 00164              STØRED A*                                         453
 A 00165 00165 00007                                                                454
 C 00162 00166 00157 00157                                                          455
 G 00167 00899 00164              STØRED A                                          456
 A 00168 00167 00161                                                                457
 C 00168 00006 00201 00201                                                          458
 H 00899 00164 00006              REPLACE STØRED A BY ZERØ                          459
 F 00158                                                                            460
*B 00201                                                                            461
 H 00899 00164 00168              STØRE (AX+AS)                                     462
 E 00158                                                                            463
*B 00157                                                                            464
 C 00900 00165 00155                                                                465
 A 00900 00900 00007              UPDATE N                                          466
 H 00899 00164 00161              STØRE AX                                          467
 H 00900 00164 00162              STØRE A*X                                         468
 V 00360 +19600000+03                                                               469
 C 00900 00360 00198                                                                470
*B 00158                                                                            471
 R 00177 00156                                                                      472
 R 00156 00178                                                                      473
 R 00178 00177                                                                      474
 F 00177                                                                            475
*B 00178                                                                            476
 M 00151 00050 00009                                                                477
 S 00151 00151 00009                                                                478
 C 00151 00057 00035                                                                479
 M 00152 00049 00009                                                                480
 S 00152 00152 00009                                                                481
 C 00152 00056 00034                                                                482
*B 00198                                                                            483
 M 00179 00900 00009                                                                484
 I 00197 +00000000+00                                                               485
 S 00197 00179 00009                                                                486
 I 00183 +00000000+00                                                               487
*B 00180                                                                            488
 A 00183 00183 00009                                                                489
 S 00184 00183 00009                                                                490
```

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                                                                                    PAGE013
                                      K=   00200

 G 00185 00899 00183                                                               491
 G 00186 00900 00183                                                               492
*B 00181                                                                           493
 A 00184 00184 00009                                                               494
 G 00187 00901 00184                                                               495
 G 00188 00902 00184                                                               496
 C 00006 00185 00193                                                               497
 R 00191 00185                                                                     498
*B 00194                                                                           499
 C 00006 00187 00195                                                               500
 R 00192 00187                                                                     501
*B 00196                                                                           502
 C 00191 00192 00182 00190                                                         503
 F 00182                                                                           504
*B 00190                                                                           505
 H 00901 00184 00185          INTERCHANGE A1+AX                                    506
 H 00902 00184 00186          INTERCHANGF A*1+A*X                                  507
 R 00185 00187                                                                     508
 R 00186 00188                                                                     509
*B 00182                                                                           510
 C 00197 00184 00181                                                               511
 H 00899 00183 00185          STØRE LARGEST A                                      512
 H 00900 00183 00186          STØRF LARGFST A*                                     513
 C 00183 00019 00499                                                               514
 C 00197 00183 00180 00499    2N-2 GREATER THAN 183 -180                           515
 F 00499                                                                           516
 R 00900 00017                                                                     517
 R 00361 00008                (361)=-1 IND. ØVERFLØW                               518
 F 00499                                                                           519
*B 00193                                                                           520
 S 00191 00006 00185                                                               521
 F 00194                                                                           522
*B 00195                                                                           523
 S 00192 00006 00187                                                               524
 E 00196                                                                           525
        FØURIER ADD + SUBTRACT                                                     526
*B 00209                                                                           527
 I 00207 +10000000+01                                                              528
 F 00210                                                                           529
*B 00208                                                                           530
 I 00207 -10000000+01                                                              531
*B 00210                                                                           532
```

```
                                        K=   00200
 M 00218 00500 00009                    2N*1
 M 00219 00700 00009                    2N SUB 2
 I 00900 +00000000+00                   N SUB 3 CØUNTER
 I 00223 +00000000+00                   BTRNST CØUNTER
 I 00221 +00000000+00                   STØRAGE CØUNTER
*B 00211
 A 00223 00223 00009
 G 00224 00699 00223                    B
 G 00225 00700 00223                    B*
 M 00224 00224 00207                    +B FØR ADD
 H 00699 00223 00224                    STØRE B
 H 00700 00223 00225                    STØRE B*
 C 00219 00223 00211
 I 00220 +00000000+00                   (220)= A CØUNTER
*B 00212
 A 00220 00220 00009
 G 00226 00499 00220                    A
 G 00227 00500 00220                    A**
 I 00222 +00000000+00                   B CØUNTER = 0 ØRIGINALY
*B 00213
 A 00222 00222 00009                    UPDATE B CØUNTER BY 2
 G 00228 00699 00222                         BX
 G 00229 00700 00222                    B*
 C 00227 00229 00214 00214              A*=B* GØ TØ 214
 A 00226 00226 00228
 H 00699 00222 00006
 H 00700 00222 00006
 C 00226 00006 00214 00214
 F 00215
*B 00214
 C 00219 00222 00213                    2N
 C 00226 00006 00483 00483
 F 00215
*B 00483
 A 00221 00221 00009                    UPDATE STØR. CTR. BY 2
 A 00900 00900 00007
 H 00899 00221 00226                    STØRE A
 H 00900 00221 00227                    STØRF A*
*B 00215
 C 00218 00220 00212                    2N*1 GET A*X+1
*B 00216
 I 00230 +00000000+00                   (230)= CØUNTER FØR B SERIES STILL STØ2
```

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                                                                                        PAGE015
                                              K=   00200
                     *R 00217                                                            575
00012                 A 00230 00230 00009          (230)+2                               576
00015                 G 00231 00699 00230          B                                     577
00292                 G 00232 00700 00230          B*                                    578
00012                 C 00231 00006 00235 00235    B=0 GO TO 35                          579
00012                 F 00236                                                            580
00017                *R 00235                                                            581
00017                 A 00221 00221 00009          UPDATE TFR + ST. CTN.                 582
00017                 A 00900 00900 00007          UPDATE N SUB 3 COUNTER                583
00265                 H 00899 00221 00231          STORF B                               584
                      H 00900 00221 00232          STORE B*                              585
                     *R 00236                                                            586
00296                 C 00219 00230 00217          2N*2) 230 GO TO 217                   587
00267 0026            E 00198                                                            588
00267 0026                      FOURIER  DIFFERENTIAL                                    589
00267 0026           *R 00240                                                            590
00258                 I 00247 +00000000+00                                               591
                      I 00248 +00000000+00                                               592
00267 002             I 00900 +00000000+00         N                                     593
                      M 00255 00700 00009          2N                                    594
00300                *R 00241                                                            595
00297                 A 00247 00247 00009                                                596
00298                 R 00256 00007                                                      597
                      G 00249 00699 00247          A                                     598
00267                 G 00250 00700 00247          A*                                    599
00312                 C 00250 00006 00246                                                600
                      S 00250 00006 00250                                                601
00017                 R 00256 00008                                                      602
00198                *R 00246                                                            603
00017                 D 00251 00250 00013                                                604
00017                 A 00251 00251 00012                                                605
00015                 S 00251 00251 00012                                                606
00014                 C 00251 00006 00257                                                607
00303                 F 00244                                                            608
00305                *R 00257                                                            609
00258                 C 00256 00006 00242 00243                                          610
                     *R 00243                                                            611
00007                 M 00252 00249 00251                                                612
00009                 R 00253 00250                                                      613
00280                 F 00245                                                            614
00307                *R 00242                                                            615
                      M 00252 00249 00251          -IA                                   616
00263
```

```
            K=   00200

                                                       700
000000+00                                              701
000000+00                                              702
                  INTEGRATE                            703
06 00313 00313    J=0 T⊘ 313                           704
06 00314 00314    J=0 IS K=0                           705
08                368=-1                               706
80                A                                    707
81 00258          1 A*                                 708
                                                       709
                  J=0,K=0                              710
97 00322          KG                                   711
80 00308          A/KG                                 712
06 00271 00272    SIN ⊘R C⊘S                           713
                                                       714
96 00321          JC                                   715
97 00322          KG                                   716
06 00305          JC+KG                                717
06 00315 00315    JC+KG=0                              718
                  IND. ⊘N PRINT ⊘UT BUT C⊘NTINUE       719
                                                       720
80 00308          A/JC+KG                              721
06 00271 00272    SIN OR C⊘S                           722
                                                       723
09                A/JC+KG OR A/KG                      724
81 00008          -A*                                  725
                                                       726
                                                       727
09 00008          -A/JC+KG ⊘R -A/KG                    728
81                A*                                   729
                                                       730
000000+00         (339)= C⊘NSTANT                      731
                  C⊘NSTANT MULTIPLY                    732
000000+00         (331)= ST⊘RAGE C⊘UNTER               733
00                                                     734
00 00500                                               735
                                                       736
31 00009          (331)+2                              737
99 00331                                               738
00 00331                                               739
35 00339          CA                                   740
31 00337          ST⊘RE A                              741
```

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            617
            618
            619
            620
            621
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            623
            624
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            626
TRACT       627
            628
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            634
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            642
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            658
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                                                                          PAGF019
                                 K=   00200

 H 00900 00331 00336              STORE A*                                742
 C 00333 00331 00334              2N GREATER THAN (631)                   743
 F 00499                                                                  744
*B 00345                                                                  745
 V 00349 +00505050+08             ARGUMENT OF TERM FOR EXTRACTION         746
 M 00350 00500 00009              2N                                      747
 I 00351 +00000000+00             (351)=0 INITIAL                         748
*B 00346                                                                  749
 A 00351 00351 00009              (351)+2                                 750
 G 00352 00500 00351                                                      751
 C 00352 00349 00347 00347        2N=(351)                                752
 G 00353 00499 00351                                                      753
 R 00901 00353                                                            754
 R 00902 00352                                                            755
 R 00900 00007                                                            756
 F 00499                                                                  757
*B 00347                                                                  758
 C 00350 00351 00346                 2N=(351)                             759
 R 00900 00006                                                            760
 F 00499                                                                  761

                                                                         0777 CARDS
```

Appendix D

Mystic Code

The Fourier Operating Package described in this report was written for the IBM 709 in Mystic Code. The following is an explanation of the Mystic Code.

```
                                                MYSTIC CODE          PAGE001
                         K=   00000

C ODF                    REMARKS                                  06/20/61

A   X Y  Z               ADD COMMAND (Y) + (Z) GO INTO LOCATION X. THAT IS,
                         ADD (Y) TO (Z) AND STORE THE RESULT IN X.

*B  X                    BEGIN POINT PSEUDO COMMAND. THE SEQUENCE OF INSTRUCTIONS
                          WHICH FOLLOW A BEGIN X IS ENTERED
                          FROM AT LEAST TWO PARTS OF THE CODING. ENTRANCE TO
                          A BEGIN INSTRUCTION CAN  BE FROM THE INSTRUCTION
                          PRECEDING IT (I.E.,A SEQUENTIAL ENTRANCE), FROM
                          A COMPARE COMMAND OR FROM AN END COMMAND. THIS
                          INSTRUCTION MAY BE THOUGHT OF AS STATING THAT THE
                          FOLLOWING INSTRUCTIONS MAY BE ENTERED BY A TRANSFER
                          TO LOCATION X.

C   X Y  Z               COMPARE (X) WITH (Y). IF (X) IS GREATER THAN (Y),GO TO
                          LOCATION Z AND EXECUTE THE INSTRUCTIONS WHICH FOLLOW
                          THE B Z OR N Z. IF (X) EQUALS OR IS LESS THAN (Y),
                          EXECUTE THE NEXT INSTRUCTION IN SEQUENCE.

C   X Y  Z Z*            COMPARE (X) WITH (Y). IF (X) IS GREATER THAN (Y), GO TO
                          LOCATION Z AND EXECUTE THE INSTRUCTIONS WHICH FOLLOW
                          THE B Z OR N Z. IF (X) IS LESS THAN (Y),GO TO LOCATION
                          Z* AND EXECUTE THE INSTRUCTIONS WHICH FOLLOW THE B Z*
                          OR N Z*. IF (X) EQUALS (Y), EXECUTE THE NEXT INSTRUC-
                          TION IN SEQUENCE.

D   X Y  Z               DIVIDE COMMAND. (Y)/(Z) GO INTO LOCATION X.
                          THAT IS, DIVIDE (Y) BY (Z) AND STORE THE RESULT IN X.

E   X                    EXIT COMMAND. UNCONDITIONAL TRANSFER TO
                          THE SET OF INSTRUCTIONS WHICH FOLLOW B X OR
                          N X.


F   X Y  Z               FUNCTION COMMAND.
                          THIS INSTRUCTION ENABLES ONE TO TRANSFER TO A
                          FUNCTION AND AFTER ITS EXECUTION, CONTINUE TO
                          THE NEXT INSTRUCTION IN SEQUENCE FOLLOWING THE
                          FUNCTION STATEMENT. Y IS THE LOCATION OF THE
                          FIRST BEGIN INSTRUCTION (B 1) IN A FUNCTION.
                          NORMALLY Z IS THE LOCATION OF THE INPUT TO THE
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                    K=   00000

                      FUNCTION,WHILE X IS THE LOCATION OF THE
                      OUTPUT. HOWEVER, THE REQUIREMENTS OF
                      FUNCTIONS DIFFER FROM FUNCTION TO FUNCTION AND
                      EACH ONE USED MUST HAVE ITS REQUIREMENTS MET
                      BEFORE TRANSFERRING TO IT. (NOTE. FUNCTIONS ARE
                      SOMETIMES REFERRED TO AS SUB-ROUTINES.)

G  X Y  Z            GET COMMAND. THE CONTENTS OF A LOCATION EQUAL
                      TO (Z) + Y GO IN TO LOCATION X. THAT IS, REPLACE
                      THE CONTENTS OF LOCATION X BY THE CONTENTS OF
                      Y + (Z).

H  X Y  Z           HOLD COMMAND. THE CONTENTS OF LOCATION Z GO INTO
                     A LOCATION = X + (Y) . THAT IS, REPLACE THE CONTENTS
                     OF X + (Y) BY THE CONTENTS OF Z.

I  X SY YYYYYYYYSEE INITIALIZE COMMAND. SET THE CONTENTS OF
                     X = S.YYYYYYYY TIMES 10 EXP SEE. S= BLANK OR +
                     MEANS POSITIVE VALUE, S= - MEANS NEGATIVE VALUE IN
                     THE MANTISSA. S IN THE EXPONENT USES THE SAME
                     SIGN NOTATION.

K  X                KEY ADDRESS PSEUDO COMMAND.
                     X=0 , SET THE K COUNTER TO ZERO. WHEN X DOES NOT
                     EQUAL ZERO, THE KEY ADDRESS IS INCREASED BY X.
                     THAT IS, THE K COUNTER + X GOES INTO THE K
                     COUNTER. THE K COUNTER IS USED TO RELOCATE
                     FUNCTIONS. THE K COUNTER IS ADDED TO THE ADDRESS
                     OF EACH INSTRUCTION DURING COMPILATION, UNLESS
                     THE ADDRESS IS IN THE LEFT HAND ADDRESS OF A
                     Q COMMAND. THE K COMMAND CLEARS THE Q TABLE
                     DURING COMPILATION.

L  X Y  Z  F1 ,F2,. ...F18,T1,T2,...T18.
                    Z= CA ,LOAD  F1 COLUMNS OF DATA INTO LOCATION X,THEN
                            LOAD  F2 COLUMNS OF DATA INTO LOCATION X+1,
                            ETC. TO MAXIMUM OF 18 FIELDS OR 72 COLUMNS.
                            T1,T2,..T18 DESCRIBE THE WAY THE DATA IS
                            STORED IN X,X+1,ETC. THE TYPE OF DATA STORED
                            IS NUMERIC OR ALPHABETIC. IF IT IS NUMERIC,
                            THE CORRESPONDING TYPE CODE IS N. IF IT IS
                            ALPHABETIC, THE CORRESPONDING TYPE CODE IS
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                  K=   07000

                  A. TYPE ØF DATA CØDE ALSØ INCLUDES S FØR
                  SKIP. WHEN THE SKIP TYPE IS USED, THIS
                  DØES NØT INVØLVE DATA STØRED IN A WØRD.
                  THUS, IF T1 IS TYPE S, T2 IS TYPE N, THE
                  L CØMMAND READS THE DATA FRØM THE F2 CØLUMN
                  INTØ WØRD X. THE CØLUMNS ARE READ STARTING
                  FRØM THE LEFT ALWAYS. SKIP FIELDS TØ THE RIGHT
                  ØF ALL ØTHER DATA NEED NØT BE DEFINED IN THE
                  L CØMMAND. THE FIRST BLANK FIELD MEANS THE REST
                  ØF THE CARD IS SKIPPED. THE NUMBER ØF CØLUMNS
                  ØF TYPE A MUST NØT EXCEED 4 PER FIELD. THE
                  NUMBER ØF CØLUMNS ØF TYPE N MUST NØT EXCEED 9
                  PER FIELD INCLUDING THE SIGN. THE NUMBER ØF
                  CØLUMNS ØF TYPE S MUST NØT EXCEED 15 PER FIELD.
                  IF 1 CARD IS TØ BE LØADED ACCØRDING TØ THE
                  GIVEN FØRMAT, (Y) = 1. IF I CARDS ARE TØ BE
                  LØADED ACCØRDING TØ THF GIVEN FØRMAT,
                  (Y)= I,THE NUMBER ØF CARDS. THE DATA FØR
                  EACH CARD IS CØNSECUTIVELY STØRED IN THE SAME
                  WAY AS THAT FØR THF FIRST. THE DATA FØR THF
                  FIRST WØRD ØF INPUT FRØM CARD J+1 FØLLØWS
                  CØNSECUTIVELY THF LAST WØRD ØF INPUT FRØM
                  CARD J. (Y) MUST BF AN INTEGER THAT IS AT LEAST 1.
              Z= TA ,LØAD  TAPE B1 BCD.     SAME FØRMAT DESCRIPTIØN
              Z= TB ,LØAD  TAPE B2 BCD.      AS ABØVE IN Z= CA,
              Z= TC ,LØAD  TAPE B3 BCD.      REPLACING CARD BY BCD
              Z= TD ,LØAD  TAPE B4 BCD.      RECØRD AND LØAD BY
              Z= TE ,LØAD  TAPE B5 BCD.      THE APPRØPIATE READ
              Z= TF ,LØAD  TAPE B6 BCD.      TAPE DESIGNATIØN.
              Z= TG ,LØAD  TAPF B7 BCD.
              Z= TA ,(Y) =I , BLANK F1 THRØUGH F18 AND T1 TØ T18.
              Z= TB ,(Y) =I , BLANK F1 THRØUGH F18 AND T1 TØ T18.
              Z= TC ,(Y) =I , BLANK F1 THRØUGH F18 AND T1 TØ T18.
              Z= TD ,(Y) =I , BLANK F1 THRØUGH F18 AND T1 TØ T18.
              Z= TE ,(Y) =I , BLANK F1 THRØUGH F18 AND T1 TØ T18.
              Z= TF ,(Y) =I , BLANK F1 THRØUGH F18 AND T1 TØ T18.
              Z= TG ,(Y) =I , BLANK F1 THRØUGH F18 AND T1 TØ T18.
           IF I = 0,   THE CØMMAND IS TØ BACKSPACE A FILE.
           IF I = -N   THE CØMMAND IS TØ BACKSPACE N RECØRDS.

L  X Y  Z     Z= CAB, LØAD INTØ X,X+1,ETC. BINARY CARDS
                   HAVING THE NUMBER ØF WØRDS SPECIFIED
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                          IN THE CONTENTS OF Y.
                     Z= TAB, LOAD TAPE B1 BINARY.       LOAD INTO X,X+1,ETC.
                     Z= TBB, LOAD TAPE B2 BINARY.        A BINARY RECORD
                     Z= TCB, LOAD TAPE B3 BINARY.        HAVING THE NUMBER
                     Z= TDB, LOAD TAPE B4 BINARY.        OF WORDS SPECIFIED
                     Z= TEB, LOAD TAPE B5 BINARY.        IN THE CONTENTS OF
                     Z= TFB, LOAD TAPE B6 BINARY.        Y.
                     Z= TGB, LOAD TAPE B7 BINARY.

M  X Y  Z            MULTIPLY COMMAND. (Y) TIMES (Z) GOES INTO X.
                      THAT IS, THE PRODUCT (Y)(Z) REPLACES THE
                      CONTFNTS OF X.

N  X                 NOTE COMMAND. NOTE THAT THE FOLLOWING COMMAND
                      SEQUENCE BEGINS WITH X. N X IS NORMALLY USED
                      TO BEGIN SEVERAL COMMAND SEQUENCES. THE N X
                      EXECUTED LATEST IS THE COMMAND SEQUENCE TO
                      BE FOLLOWFD WHFN AN UNCONDITIONAL TRANSFER
                      OR A CONDITIONAL TRANSFER TO X IS MADE. THF N X
                      IS A VARIABLE CONNFCTOR.

O  X                 ORIGIN COMMAND. THE COMPILATION WILL GENERATE
                      MACHINE LANGUAGE CODE FROM LOCATION X TO A
                      MAXIMUM OF 30,000.

P  X Y  Z  F1 ,F2,. .. F18,T1,T2,...T18.
                     Z= CA ,PUNCH F1 COLUMNS OF DATA FROM LOCATION X,THEN
                            PUNCH F2 COLUMNS OF DATA FROM LOCATION X+1,
                            ETC. TO MAXIMUM OF 18 FIELDS OR 72 COLUMNS.
                            T1, T2,..T18 DESCRIBE THE WAY THE DATA IS
                            STORED IN X,X+1,ETC. THE TYPE OF DATA STORED
                            IS NUMERIC OR ALPHABETIC. IF IT IS NUMERIC,
                            THE CORRESPONDING TYPE CODE IS N. IF IT IS
                            ALPHABETIC, THE CORRESPONDIND TYPE CODE IS
                            A. TYPE OF DATA CODE ALSO INCLUDES S FOR
                            SKIP. WHEN THE SKIP TYPE IS USED, THIS
                            DOES NOT INVOLVE DATA STORED IN A WORD.
                            THUS, IF T1 IS TYPE S, T2 IS TYPE N, THE
                            P COMMAND GETS THE DATA FOR THE F2 COLUMNS
                            FROM WORD X. THE COLUMNS ARE BUILT UP STARTING
                            FROM THE LEFT ALWAYS. SKIP FILEDS TO THE RIGHT
                            OF ALL OTHER DATA NEED NOT BE DEFINED IN THE
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              P COMMAND. THE FIRST BLANK FIELD MEANS THE REST
              OF THE CARD IS SKIPPED. THE NUMBER OF COLUMNS
              OF TYPF A MUST NOT EXCFED 4 PER FIELD. THF
              NUMBER OF COLUMNS OF TYPE N MUST EXCEED 9
              PER FIELD INCLUDING THE SIGN. THE NUMBER OF
              COLUMNS OF TYPE S  MUST NOT EXCEED 15 PER FIELD.
              IF 1 CARD IS TO BE PUNCHED ACCORDING TO THE
              GIVEN FORMAT, (Y) = 1. IF I CARDS ARE TO BE
              PUNCHED ACCORDING TO THE GIVEN FORMAT,
              (Y)= I,THE NUMBER OF CARDS. THE DATA FOR EACH
              CARD MUST BE CONSECUTIVELY STORED IN THE SAME
              WAY AS THAT FOR THF FIRST. THE DATA FOR THE
              FIRST WORD OF OUTPUT FOR CARD J+1 MUST FOLLOW
              CONSECUTIVELY THE LAST WORD OF OUTPUT FOR
              CARD J. (Y) MUST BE AN INTEGER THAT IS AT LEAST
     Z= PA ,PRINT.  INSERT PRINT FOR PUNCH IN THE DESCRIP-
              TION ABOVE TO INTERPRET AN INSTRUCTION TO PRINT
              ON THE ON-LINE PRINTER. LINE REPLACES CARD IN
              THE EXPLANATION ABOVE.
     Z= TA ,WRITE TAPE B1 BCD.      SAME FORMAT DESCRIPTION
     Z= TB ,WRITE TAPE B2 BCD.       AS ABOVE IN Z= CA,
     Z= TC ,WRITE TAPE B3 BCD.       REPLACING CARD BY BCD
     Z= TD ,WRITE TAPE B4 BCD.       RECORD AND PUNCH BY
     Z= TE ,WRITE TAPE B5 BCD.       THE APPROPIATE WRITE
     Z= TF ,WRITE TAPE B6 BCD.       TAPE DESIGNATION.
     Z= TG ,WRITE TAPE B7 BCD.
     Z= TA ,(Y) =I , BLANK F1 THROUGH F18 AND T1 TO T18.
     Z= TB ,(Y) =I , BLANK F1 THROUGH F18 AND T1 TO T18.
     Z= TC ,(Y) =I , BLANK F1 THROUGH F18 AND T1 TO T18.
     Z= TD ,(Y) =I , BLANK F1 THROUGH F18 AND T1 TO T18.
     Z= TE ,(Y) =I , BLANK F1 THROUGH F18 AND T1 TO T18.
     Z= TF ,(Y) =I , BLANK F1 THROUGH F18 AND T1 TO T18.
     Z= TG ,(Y) =I , BLANK F1 THROUGH F18 AND T1 TO T18.
IF I = 0,     THE COMMAND IS TO WRITF AN END OF FILF MARK
              ON THE APPROPIATE TAPE.
IF I = -1,    THE COMMAND IS TO REWIND THE APPROPIATE TAPE.

P  X Y  Z
     Z= CAB, PUNCH FROM X,X+1,ETC. UP TO THE NUMBER OF
             WORDS SPECIFIED IN (Y) TO CARDS IN BINARY
             FORM.
     Z= TAB, WRITE TAPE B1 BINARY.        WRITE FROM X,X+1,
     Z= TBB, WRITE TAPE B2 BINARY.         ETC. UP TO THE
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                          K=   07000

                         Z= TCB, WRITE TAPE B3 BINARY.       NUMBER OF WORDS
                         Z= TDB, WRITE TAPE B4 BINARY.       SPECIFIED IN THE
                         Z= TEB, WRITE TAPE B5 BINARY.       CONTENTS OF Y.
                         Z= TFB, WRITE TAPE B6 BINARY.
                         Z= TGB, WRITE TAPE B7 BINARY.

Q  X Y                  THE Q COMMAND ENABLES ONE TO FIX ADDRESSES. THE
                         K COUNTER MODIFIES EVERY ADDRFSS EXCEPT EACH ONE
                         EQUAL TO AN X IN A Q COMMAND. EACH SUCH ADDRFSS
                         IS THEN CHANGED DURING COMPILATION TO THE ADDRESS
                         GIVEN IN THE Y ADDRESS OF THE Q COMMAND. THE
                         Q TABLE IS CLEARED BY A K COMMAND DURING COMPILATION.
                         THIS ENABLES ONE TO HAVE A SEPARATE Q TABLF FOR EACH
                         FUNCTION. THE Q COMMAND MUST PRECEDE THE INSTRUCTIONS
                         IT IS TO CONTROL. IT IS GOOD PRACTICE TO HAVE THE
                         Q COMMANDS PRECEDE ANY OTHER INSTRUCTIONS WHICH
                         FOLLOW A K COMMAND.

R  X Y                   REPLACE COMMAND.
                          REPLACE THE CONTENTS OF X BY THE CONTENTS OF Y.

S  X Y  Z                SUBTRACT COMMAND. REPLACE THE CONTENTS OF X BY
                          (Y) - (Z).

    T XX...X             TITLE COMMAND. THE CHARACTERS IN A TITLE COMMAND MAY
                          GO FROM COL.2 TO COL.71. THEY CONTROL COL.
                          1 TO COL.70 OF AN OUTPUT CARD, PRINTER LINE, OR
                          BCD LISTED LINE. A TITLE COMMAND NEED NOT PRECEDE
                          EACH P COMMAND. THE LATEST T EXECUTED IS THE
                          ONE IN POWER. IF NO TITLF INFORMATION IS DFSIRFD
                          FOR THE OUTPUT, THE T COMMAND SHOULD HAVE COL.
                          2 TO 71 BLANK. IF TITLE INFORMATION IS DESIRED,
                          IF SHOULD BF ARRANGFD SO THAT IT WILL CONTROL
                          ONLY BLANK COLUMNS OF THF P COMMAND.

V  X SY YYYYYYYSEE       VALUE PSEUDO COMMAND. THE VALUE REPRESENTED AS A NORMALIZED
                          FLOATING POINT NUMBER IS STORED IN X DURING
                          COMPILATION. THE VALUE COMMAND IS EXECUTED ONLY
                          DURING COMPILING. SEE INITIALIZE COMMAND FOR FORMAT
                          OF VALUF.

W  X YY YY               WORD PSEUDO COMMAND.  THE WORD YYYY IS STORED IN ALPHABETIC
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                                                MYSTIC CODE            PAGE007
        K=   07000

C⊙DE IN L⊙CATI⊙N X. YYYY MAY BE NUMERIC ⊙R ALPHABETIC
CHARACTFRS.



                                                                      0255 CARDS
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NASA-Langley, 1961 D-1078